Process Specification for Dry-Film Lubricant Application

Engineering Directorate

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Prepared by: ***Signature on file*** ***5/18/10***
Daila Gonzalez — Date
Materials and Processes
Branch/ES4

Approved by: ***Signature on file*** ***5/18/10***
Bradley S. Files — Date
Materials and Processes
Branch/ES4

REVISIONS		
VERSION	CHANGES	DATE
--	Original version	5/14/96
A	New format, title change, author change, re-wrote section 2.0, expanded section 3.0, specified 220 mesh alumina for grit blasting Ni alloys and stainless steels, made burnishing standard, revised storage time limits in section 6.1.3.	7/26/99
B	Changed EM references to ES, clarified passivation requirements for nickel-based and stainless steel alloys.	11/14/02
C	Updated time and temperatures for curing Everlube 811 and Everlube 812, added Ecoalube 642, added processing requirements for copper-based alloys, added notes to designers in section 3.0, added clarifications related to in-process rework, burnishing, and thickness measurements, reordered subsections of section 6.0 and added section 6.2 on dry film application requirements, provided exception to thickness verification for threaded fasteners, updated military specifications for dry film lubricants, updated surface pre-treatment for aluminum alloys, removed requirement for phosphate coating of steel alloys, clarified masking tape requirements, disallowed thickness measurement by micrometer.	3/27/2009

D	Minor grammatical changes; removed the statement “For best adhesion, hard anodize (Type III) with a water seal is preferred” from section 3.0 and subsection 6.1.2.1; added sentences to section 3.0 stating that 1) the use of a teflon-impregnated anodic coating is preferable for aluminum alloy components, 2) Tufram H is generally applied to anodized aluminum alloy components, instead of applying a dry-film lubricant post anodizing, and 3) blasting is not required when applying Tufram H to an anodized aluminum alloy component; added sentence to section 3.0 and subsection 6.1.2.1 specifying to glass bead blast aluminum alloy components post anodizing if applying dry-film lubricants; changed title on subsection 6.1.2.6; added third paragraph to subsection 6.1.2.6 specifying the use of size 10 (200 mesh) glass beads to blast aluminum alloy surfaces with a 20lb blast as a surface pretreatment; added sentence to subsection 6.1.4 specifying that rework shall include stripping the anodic coating completely and re-applying it, glass bead blasting, and solvent cleaning for aluminum alloy surfaces that exceed the time limit stated in subsection 6.1.3.	05/12/2010

1.0 SCOPE

This process specification establishes the engineering requirements for the use of dry-film lubricants that are applied to metallic parts used in flight hardware manufactured by JSC or provided to JSC by an outside vendor.

2.0 APPLICABILITY

This process specification applies to phenolic resin-bonded (Everlube 620C), silicate-bonded (Everlube 811, Everlube 812) and epoxy-bonded (Ecoalube 642, Tiolube 460) dry-film lubricants. Specifically, it addresses the brush or spray application of these lubricants and their cure times at elevated temperatures.

3.0 USAGE

This process specification shall be called out on the engineering drawing by identifying the surface(s) to be coated and using a drawing note that identifies the lubricant. One example of the standard callout is:

APPLY *{lubricant designation}* **DRY-FILM LUBRICANT PER NASA/JSC PRC-8001**

This specification controls the curing time/temperature (section 6.3) and the thickness (section 6.5) for the dry-film lubricants listed. For lubricants not listed in this specification, the material, thickness, and curing time/temperature shall be specifically called out on the drawing in a manner similar to the following example:

APPLY *{lubricant designation}* **DRY-FILM LUBRICANT PER NASA/JSC PRC-8001, COATING THICKNESS 0.xxxx to 0.yyyy INCHES. CURE AT** *{temperature}* **$\pm$ 10 °F FOR** *{time}* **HOURS.**

Burnishing of the cured dry-film coating is standard. If a burnished coating is not desired, a note of **“DO NOT BURNISH”** shall be included on the drawing.

It is difficult or impossible to apply dry-film lubricant with a uniform thickness on internal surfaces and radii. Functional surfaces shall be marked for coating. Other surfaces should be flagged as **“OVERSPRAY ACCEPTABLE”** or **“NO DRY-FILM ON THIS SURFACE”**.

The dry-film lubricants that are standard for this specification consist of molybdenum disulfide (MoS_2) particles or MoS_2/graphite particles that are held together by a binder. Everlube 811 and Everlube 812 have a silicate binder, which make them good in specialized applications, such as when liquid oxygen

(LOX) compatibility is required. However, dry-film lubricants with silicate binders are many times not a good choice for spaceflight hardware because they are not as durable as dry-film lubricants with phenolic resin-based binders, such as Everlube 620C. Tiolube 460 and Ecoalube 642 use epoxy-based binders and are often used for ground support equipment or situations such as on the threads of bolts that are not planned to be removable.

The dry-film lubricant and its material specification (if applicable) shall be called out in the parts list similar to the following:

Part Number	Description	Material	Specification
Everlube 620C	Dry-Film Lubricant	MoS_2 with resin binder	AS5272C Type I
Everlube 811	Dry-Film Lubricant	MoS_2/graphite with silicate binder	MIL-PRF-81329D
Everlube 812	Dry-Film Lubricant	MoS_2 with silicate binder	MIL-PRF-81329D
Tiolube 460	Dry-Film Lubricant	MoS_2 with epoxy binder	AS5272C Type II
Ecoalube 642	Dry-Film Lubricant	MoS_2 with epoxy binder	AS5272C Type II

The Everlube and Ecoalube products are produced by Metal Improvement Co. and Tiolube products are manufactured by the Tiodize Corporation.

When considering applying a dry-film lubricant to an aluminum alloy component, a materials engineer should be consulted, since it is not usually the best design solution. The use of a teflon-impregnated anodic coating is preferable. For example, Tufram H is generally applied to anodized aluminum alloy components, instead of applying a dry-film lubricant post anodizing. Blasting is not required when applying Tufram H to an anodized aluminum alloy component. However, if a dry-film lubricant must be applied to an aluminum component, it must be anodized per PRC-5006 prior to glass bead blasting the region where the dry-film lubricant will be applied.

For nickel-based and stainless steel alloys, the entire component must be passivated per PRC-5002 prior to grit blasting the region where the dry-film lubricant will be applied. Passivation can be waived only if every surface of the component will have dry-film lubricant applied. When this is the case, functional surfaces should be designated on the engineering drawing. More detailed requirements for surface preparation are found in section 6.1.2.

Dry-film lubricants are mechanically bonded to metal surfaces and these surfaces must be roughened to promote lubricant adhesion. This is normally accomplished by abrasive blasting or glass bead blasting of the surface before coating. For best adhesion and wear resistance, the pre-coating surface roughness should normally be specified on the engineering drawing to be 32 rms (nominally) or rougher. Usually this is accomplished with a drawing note pointing to the specific surface involved and indicating the surface roughness. Special requirements for lower surface roughness and finer abrasives generally require additional process development time and test specimens to qualify the new techniques.

3.1 WORK INSTRUCTIONS

Work instructions shall be generated for implementing this process specification. The work instructions shall contain sufficient detail to ensure that the manufacturing process produces consistent, repeatable products that comply with this specification.

4.0 REFERENCES

ANSI B46.1	*Surface Texture (Surface Roughness, Waviness, and Lay)*
AS5272C	*Lubricant, Solid Film, Heat Cured, Corrosion Inhibiting*
ASTM F22	*Standard Test Method for Hydrophobic Surface Films by the Water-Break Test*
ASTM D740	*Standard Specification for Methyl Ethyl Ketone*
MIL-PRF-81329D	*Performance Specification, Lubricant, Solid Film, Extreme Environment*
Processing Bulletin 3000-A	*Solid Film Lubricants and Engineered Coatings (Everlube Products, 9/8/2004)*
Processing Bulletin 3002-A	*Inorganic Solid Film Lubricants (Everlube Products, 9/9/2004)*
Technical Data Sheet	*Everlube 620C (Everlube Products, 2/14/2006)*
Technical Data Sheet	*Ecoalube 642 (Everlube Products, 3/19/2008)*
Technical Data Sheet	*Everlube 811 (Everlube Products, 10/16/2003)*

Technical Data Sheet	*Everlube 812 (Everlube Products, 1/18/2008)*
Bulletin 460/588	*Tiolube 460 (Tiodize Company, Inc.)*

5.0 MATERIAL REQUIREMENTS

None identified.

6.0 PROCESS REQUIREMENTS

6.1 PRE-LUBRICANT SURFACE PREPARATION

The surfaces to be lubricated shall meet the following requirements:

6.1.1 Initial Surface Roughness

The surface roughness prior to surface pretreatment shall be observed to be as-specified on the engineering drawing by comparing with a surface standard. Any excessive machining marks, burrs, or other anomalies shall be submitted for re-work prior to surface pretreatment and dry-film application. In addition, there shall be no evidence of foreign matter, grease, oil, tarnish, scale, corrosion or other contaminants.

6.1.2 Surface Pretreatment

The surface to be coated with dry-film lubricant shall be pretreated as follows:

6.1.2.1 Aluminum Alloys
Surface pretreatment for aluminum alloys shall consist of the application of an anodic coating per PRC-5006, Type II or Type III, as-specified on the engineering drawing. The component shall be glass bead blasted post anodizing per section 6.1.2.6 if applying a dry-film lubricant.

6.1.2.2 Nickel-based and Stainless Steel Alloys
Nickel-based and stainless steel alloys shall first be passivated per PRC-5002. However, if all component surfaces are to be coated with dry-film lubricant, passivation can be waived. Following passivation, the component shall be abrasive blasted per section 6.1.2.6. If the components are plated, a materials engineer shall be consulted to determine appropriate surface pretreatment for the component.

6.1.2.3 Titanium Alloys
Titanium alloys shall be abrasive blasted per section 6.1.2.6, using aluminum oxide (alumina) or other material that is specifically approved for use on titanium.

6.1.2.4 Steel Alloys

Steel alloys shall be abrasive blasted per section 6.1.2.6.

6.1.2.5 Copper-based Alloys

Copper-based alloys shall be glass bead blasted with 80/120 or with the finer 100/200 glass bead, depending on the component size. The blaster pressure and distance from the surface shall be controlled to obtain the required surface roughness without removing a significant quantity of material.

6.1.2.6 Blasting

Blasting is essential in order to obtain good surface adhesion of the bonded dry-film lubricant. Blasting should be just enough so that the entire surface to be coated has a matte finish. Every effort should be made to remove only as much material as needed to obtain a matte finish. The blaster pressure and distance from the surface shall be controlled to obtain the required surface roughness without rounding radii or removing a significant quantity of material.

Surfaces of nickel-based alloys, stainless steel alloys, and steel alloys shall be abrasive or “grit” blasted with clean, dry alumina in the range of 120-220 mesh, in order to achieve a surface roughness of approximately 32 Ra that will generally work for most spaceflight applications. Selection of specific alumina mesh depends on the component size and surface area of the dry-film application. In addition, for some small and delicate parts, a very fine 320 mesh garnet abrasive grit may be required to prevent warping during surface preparation. Alternate grit or media may be used when verified on a test coupon or when specified explicitly on the engineering drawing.

Aluminum alloy surfaces shall be glass bead blasted post anodizing if applying a dry-film lubricant. Size 10 (200 mesh) glass beads blasted with a 20lb blast are preferable when applying a dry-film lubricant on aluminum alloy surfaces with type II, class 1 anodize.

6.1.2.7 Solvent Cleaning

After the final surface pretreatment step (glass bead blasting, abrasive blasting, or anodic coating), parts shall be cleaned. Cleaning may use any technique capable of removing particulate and organic surface contamination. The cleaning shall be finished with a non-filming solvent. The cleaning process, specific to material group and pretreatment method, shall be capable of passing a 30 second ASTM F22 water break test.

6.1.3 Prepared Surface Storage Requirements and Time Limits

If the dry-film lubricant will not be applied immediately after the final surface pretreatment step, the prepared surface must be protected against corrosion and contamination. To minimize oxidation and corrosion, the maximum elapsed time between the last step of surface pretreatment (prior to solvent cleaning) and the lubricant application shall be as follows:

(a) Aluminum Alloys – 8 hours
(b) Nickel-based and Stainless Steel Alloys – 8 hours
(c) Titanium Alloys – 2 hours
(d) Steel – 8 hours
(e) Copper-based Alloys – 4 hours

The time limit for pre-treated parts may be extended indefinitely if stored in a humidity controlled (<40%) environment or stored with non-dusting desiccants. In addition, the time limit may be extended indefinitely for pre-treated parts that are stored in a dry, clean argon or nitrogen environment.

6.1.4 In-Process Rework

Part surfaces treated per 6.1.2 that exceed the specified time limitations of 6.1.3 shall be completely reprocessed, with the exception of copper-based alloys which may be vapor degreased only prior to lubricant application. Otherwise, rework shall include grit blasting and solvent cleaning. For aluminum alloys that exceed the time limitation, rework shall include stripping the anodic coating completely and re-applying it, glass bead blasting, and solvent cleaning.

6.1.5 Surface Condition

Surfaces shall be examined before application of the dry-film lubricant. The surface condition shall be uniform in appearance and free from visible defects such as nicks, scratches, burrs, or other surface irregularities. There shall be no evidence of grease, oil, grit, tarnish, rust, scale, corrosion or other contaminants when wiped with a clean white cloth.

6.2 DRY-FILM LUBRICANT APPLICATION

The dry-film lubricant shall be applied using a spray gun or air brush in several thin, uniform coats. Each coat shall be allowed to dry before applying the next coat. All parts shall be air dried at room temperature for a minimum of 30 minutes prior to the curing cycle. Depending on atmospheric conditions, this drying process may be longer and should be continued until the film is dry.

6.3 CURE TIME AND TEMPERATURE

The time/temperature cycle needed to cure the lubricant shall be as-listed below. For lubricants not listed, the cure time/temperature shall be as-specified on the engineering drawing.

Everlube 620C:

(a) Aluminum Alloys	300 ± 10 °F for 1 hour
(b) Ni-based Alloys, Stainless Steels	375 ± 10 °F for 1 hour
(c) Titanium Alloys	375 ± 10 °F for 1 hour
(d) Steel Alloys*	375 ± 10 °F for 1 hour
(e) Cu-based Alloys	300 ± 10 °F for 1 hour

Everlube 811 and Everlube 812:

175 ± 10 °F for 2 hours followed by:

(a) Aluminum Alloys	325 ± 10 °F for 2 hours
(b) Ni-Based Alloys, Stainless Steels	400 ± 10 °F for 2 hours
(c) Titanium Alloys	400 ± 10 °F for 2 hours
(d) Steel Alloys*	400 ± 10 °F for 2 hours
(e) Cu-based Alloys	325 ± 10 °F for 2 hours

Tiolube 460:

(a) Aluminum Alloys	350 ± 10 °F for 1.5 hours
(b) Ni-Based Alloys, Stainless Steels	400 ± 10 °F for 1 hour
(c) Titanium Alloys	400 ± 10 °F for 1 hour
(d) Steel Alloys*	400 ± 10 °F for 1 hour
(e) Cu-based Alloys	325 ± 10 °F for 1 hour

Ecoalube 642

(a) Aluminum Alloys	325 ± 10 °F for 1 hour
(b) Ni-based Alloys, Stainless Steels	400 ± 10 °F for 1 hour
(c) Titanium Alloys	400 ± 10 °F for 1 hour
(d) Steel Alloys*	400 ± 10 °F for 1 hour
(e) Cu-based Alloys	325 ± 10 °F for 1 hour

*NOTE: For steel alloys that are tempered below the temperature specified in these tables (such as steel 52100), the curing temperature must be adjusted. A materials engineer shall be consulted to ensure that a proper curing temperature is selected.

6.4 BURNISHING

Unless specified otherwise on the engineering drawing, the cured dry-film coating shall be burnished with a clean white cloth or fine white scotchbrite, using light hand pressure until the surface takes on a glossy metallic sheen. For threaded fasteners, burnishing is accomplished by threading and unthreading the components. For pin and hole applications, burnishing may involve repeated surface contact of the components.

6.5 DRY-FILM LUBRICANT THICKNESS

The final dry-film lubricant thickness after burnishing shall be as-specified below. For lubricants that are not listed below, the thickness shall be as-specified on the engineering drawing.

Everlube 620C	0.0003 to 0.0005 inches
Everlube 811 and Everlube 812	0.0003 to 0.0005 inches
Tiolube 460	0.0003 to 0.0005 inches
Ecoalube 642	0.0003 to 0.0005 inches

7.0 PROCESS QUALIFICATION

The bonded dry-film lubricant process shall be qualified on sample plates for each metal pretreatment type to assure effectiveness prior to application on production parts. Qualification shall show that the process (including pre-treatment) is capable of meeting all requirements of this specification. Any change in processing parameters or lubricant material will require requal-ification.

8.0 PROCESS VERIFICATION

8.1 APPEARANCE

When visually examined in its finished form, at least 95 percent of the bonded lubricant coating shall appear uniform and smooth, free from cracks, scratches, blisters, pinholes, bubbles, runs, sags, foreign matter, grit, rough particles, separation of ingredients or other surface imperfections. The remaining area shall be free of burrs and other imperfections detrimental to lubricity.

8.2 FILM ADHESION

After application, cure, and burnishing, the lubricant shall show good adhesion to the substrate by using a tape peel test (masking tape with a minimum adhesive strength of 28 kg/m (25 oz/in) is applied to the functional surface and then is removed in one abrupt motion). A uniform deposit of powdery material may adhere to the tape, but the lifting of any flakes or lubricant particles that expose any part of the surface under the dry-film lubricant is unacceptable. This film adhesion tape peel test shall be performed on each component in the lot.

8.3 SOLVENT WIPE TEST

Resin-bonded dry-film lubricants, such as Everlube 620C, shall show good adhesion to the prepared surface when subjected to the following solvent wipe test. For each lot of items that are processed together at one time, the lubricant of a representative component shall be wiped using a clean, cotton swab that is saturated with methyl ethyl ketone (MEK) solvent has been purchased to meet ASTM D740. Each dry-filmed surface shall be wiped at a random location that characterizes the functional surface, with a minimum of 50 strokes in order to lend confidence that the dry-film lubricant will not flake off. A uniform transfer of material may adhere to the cotton swab, but the removal of flakes or lubricant particles that expose any part of the surface under the dry-film lubricant is unacceptable and shall be cause for rejection of the lot.

Silicate-bonded and epoxy-bonded dry-film lubricants do not require this solvent wipe test.

8.4 DRY-FILM LUBRICANT THICKNESS

The dry-film application process shall be controlled to ensure that the coating thickness is within specification. As verification, thickness shall be measured for the functional surfaces of each component after the cure cycle and burnishing steps have been completed. The measurements may be made either on the actual dry-film coated parts or on test coupons processed together with the parts. Lots of greater than 10 components that have been processed together shall only require thickness measurements of a random sample of 20% of the lot. If there are any discrepancies in this subset, 100% inspection is required. For internally and externally threaded fasteners, the cured dry-film lubricant shall demonstrate complete coverage, but measurement for thickness verification is not required. Internally threaded fasteners shall permit a minimum of three-quarters turn on corresponding external threads. The following thickness measurement techniques are acceptable: eddy-current thickness gage, magnetic induction thickness gage, and the difference in lubricated and pretreated measurements using a precision height gage with 0.0001 inch measuring capability. Each measurement shall be the average of 6 readings minimum.

9.0 TRAINING AND CERTIFICATION OF PERSONNEL

All bonded dry-film lubricant operations shall be performed by personnel who have been trained for this process and have successfully performed a coating qualification to this specification.

10.0 DEFINITIONS

Dry-film lubricant	Dry coating consisting of powder lubricants that are bonded in a solid matrix to provide lubrication to component(s) that are coated.
Functional surface	The dry-filmed surface that is subject to a wear environment.
Lot	A batch of components that have been processed together at one time, with dry-film lubricant spray application of parts in a continuous manner and cured together in the furnace.